Ontario Ministry of Labour
Workers' Compensation Board of Ontario
Atomic Energy Control Board of Canada

STUDY OF MORTALITY OF

ONTARIO GOLD MINERS 1955 - 1977

ADDENDUM

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Introduction

Following the release of the "Study of Mortality of Ontario Gold Miners 1955 - 1977" in July 1986 certain questions were raised by the Ontario Workers' Compensation Board and by other readers of the report. It was felt that further information assembled in this context might be of interest to readers of the July 1986 report and this addendum is therefore made available.

Additional description of data

Certain facts that might help in the interpretation of the data were not described in the earlier reports in sufficient detail.

The report on the Study of Mortality of Ontario Miners (1983) defines (see page 11) a gold miner as a non-uranium miner who has spent 85% or more of his total mining experience in and outside Ontario, in an Ontario gold mine. The report does not state at what point in time the 85 percent criterion was evaluated. This was done at the time of leaving the study at the end of 1977, at death or when qualifying as an uranium miner.

The question has been raised if the increased lung cancer rates in gold miners possibly are the result of an nosological artefact. The much greater incidence of silicosis in gold and mixed ore miners might have resulted in more lung cancers being falsely diagnosed in these two cohorts because of pulmonary symptoms and radiologically abnormal lungs. It should be stated, that practically all the lung cancer cases diagnosed in local hospitals in the mining areas were sent for further investigation and treatment to the major teaching hospitals in Toronto or a major hospital in Sudbury.

Out of a total 165 lung cancer deaths in gold miners histological confirmation was obtained from the hospital, and/or through reevaluation of tissues as part of this study in 143 cases including 133 tissue samples and 10 cytological results from sputum samples. In other cases the hospital records could not be located or were known to have been destroyed. In these cases no information on histological confirmation could be obtained. In some cases there was possibly no histological confirmation. If it is assumed that in all silicotics with the diagnosis of lung cancer with no histological confirmation known to the authors of the report (3 cases) the cause of death was not lung cancer, the number of lung cancer deaths would decline from 165 to 162 deaths. The observed number of lung cancer deaths would still be significantly greater than expected (SMR = 138, $p = 4 \times 10^{-5}$). Similar results were obtained for 'mixed ore miners'. It can therefore be stated that nosological errors did not affect the results of the study relating to lung cancer in any substantive way.

Mixed ore miners

The earlier study indicated a significantly increased lung cancer risk in a group called 'mixed ore miners'. These were men with 60 months or more of mining experience including 1/2 month or more in an Ontario mine as long as they did not qualify as uranium miners. The men spent less than 85% of their total mining experience mining one specific ore and were known to have had a miner's examination at some time between January 1, 1955 and December 31, 1977. A total of 101 lung cancer deaths occurred in this population, whilst only 69.48 deaths from this cause was expected.

The definition of the 'mixed ore miner' was changed to be consistent with the cohort of gold miners. A 'mixed ore miner' was now required to have worked as a miner at some time between January 1, 1955 and December 31, 1977 in order

to be included into the study. The number of expected and observed lung cancer deaths decreased as a result, but the Standard Mortality Ratio (SMR) for lung cancer was hardly affected by this change in definition from 145 in the 1983 study to 149 in this report.

Further statistical analysis of lung cancer mortality among 'mixed ore miners'

Table 1 indicates that out of 81 lung cancer deaths that occurred over the period 1955-1977 in 'mixed ore miners', that were still working in mining at some time during this period, 72 deaths occurred in men with some gold mining experience and only 9 deaths in men who never mined gold. The SMR in men who ever mined gold is significantly greater than 100. The SMR in men who never mined gold does not significantly differ from 100.

Table 2 gives data on lung cancer risk in 'mixed ore miners' by attained age group and year of first gold mining. Similarly as in gold miners there appears to be a declining risk of lung cancer with later calendar year of starting gold mining. The declining trend is statistically significant ($P = 0.01$). After adjusting for age the trend is still statistically significant ($P = 0.006$).

Table 3 gives data on lung cancer risk in mixed ore miners who ever mined gold by 4 age groups. The relative risk of lung cancer in 'mixed ore miners' who ever mined gold is not significantly increased at ages below 55 years, but significantly increased at higher age groups.

Table 4 compares the lung cancer risk in 'mixed ore miners' who started mining gold prior to 1945 with the risk in men who started mining gold in 1945 or later. No increased lung cancer risk in 'mixed ore miners' who started mining gold after 1944 was observed when compared with an appropriately matched male population of Ontario. A significantly increased lung cancer risk was, however, observed in 'mixed ore miners' who started mining gold prior to 1945.

Table 5 gives the results of an analysis of lung cancer risk in 'mixed ore miners' by years worked in gold mines prior to 1945 and by attained age group. No significant relation of years worked in gold mines prior to 1945 and lung cancer risk was found in mixed ore miners.

Table 6 indicates a greater lung cancer risk in 'mixed ore miners' with X-ray rating 4 or 5 than with X-ray rating less than 4.

These data indicate a great similarity of findings in 'mixed ore miners' with findings in gold miners reported earlier.

Further statistical analysis of stomach cancer mortality for both gold and 'mixed ore miners'

Table 7 indicates a significantly increased risk of stomach cancer only in men who started gold mining in 1945 or later. No statistically significant increased risk of stomach cancer was demonstrated in gold miners who started mining gold before 1945 and no increased risk of stomach cancer could be demonstrated in 'mixed ore miners'.

Attained age appears to have some effect on the relative risk of stomach cancer in gold miners. The relative risk tends to decline with greater attained age (See table 8).

The decrease of relative risk with attained age is statistically significant ($P = 0.007$). It should, however, be recognised that year of start of gold mining and attained age are not independent variables.

Data relating to stomach cancer in gold miners over the period 1955-1977 are summarized in Table 9. The table indicates an increased absolute and relative stomach cancer risk largely independent of calendar period, but dependent on year of start of gold mining.

The effect of calendar period, age and year of start on the relative risk of stomach cancer have been investigated using a Poisson regression analysis. The results of the analysis are given in Table 10 using the relative risk model. The effect of calendar period on risk is too small to be detectable. Both age and year of start of gold mining do, however, have a measurable effect on risk (see note table 10).

The results of the analysis of stomach cancer risk are given, but no interpretation of these results is offered. It should be noted that the overall number of stomach cancer cases in gold and in 'mixed ore miners' is small and the increase in risk is also moderate (SMR about 150). Further subdivision for the purpose of analysis leads to highly uncertain results.

Mortality outcomes for lung cancer risk by calendar period of starting gold mining

The data for 'mixed ore miners' are given in table 2 and for gold miners in table 11. The number of expected and observed cases in individuals who started gold mining in 1955 and later is too small to allow interpretation. If the study is updated to 1984 interpretation might be easier.

Conclusions:

1. A significantly increased lung cancer risk was observed in 'mixed ore miners' who ever mined gold. No such increase could be detected in 'mixed ore miners' who never mined gold.

2. The relative lung cancer risk in 'mixed ore miners' is not significantly increased at ages below age 55 years. It is, however, significantly increased in age groups above 55 years. In gold miners the risk is increased in all age groups above 45 years.

3. As in gold miners, the lung cancer risk in 'mixed ore miners' was elevated in early starters as compared to late starters.

4. Similarly as in gold miners there was an association of X-ray rating and lung cancer risk.

5. These similarities indicate that the increased lung cancer risk observed in 'mixed ore miners' is largely the result of their employment in gold mines.

6. The increased risk of stomach cancer in gold miners was detectable only in men who started gold mining after 1945. The risk decreased with increasing age. The risk in late starters was significantly greater than in early starters. In this respect stomach cancer risk greatly differs from lung cancer risk in gold miners.

7. No significantly increased risk of stomach cancer was detected in 'mixed ore miners'.

8. No explanation for these findings in relation to stomach cancer is offered at present.

TABLE 1

LUNG CANCER - MIXED ORE MINERS
EVER MINED GOLD AND NEVER MINED GOLD

Group	Observed	Expected	SMR	P-Value
Ever Mined Gold In Ontario	72	47.87	150	7×10^{-4}
Never Mined Gold In Ontario	9	8.05	112	0.4
Total	81	55.91	145	1×10^{-3}

Table 2

MIXED ORE MINERS - WHO EVER MINED GOLD
LUNG CANCER RISK
BY ATTAINED AGE AND YEAR OF FIRST GOLD MINING

	Under 65				Over 65			
Year of first Gold Mining	Observed	Expected	SMR	P-Value	Observed	Expected	SMR	P-Value
before 1935	11	4.97	221	0.01	18	10.48	172	0.02
1935-1944	17	8.42	202	0.006	9	5.77	156	0.1
1945-1954	11	9.80	112	0.4	2	1.96	102	0.6
1955+	4	5.68	70		0	0.78	0	
Total	43	28.87	149	0.008	29	19.00	153	0.02

P-value - one sided test of no increase in risk.

Table 3

MIXED ORE MINERS - EVER MINED GOLD
LUNG CANCER RISK
BY ATTAINED AGE GROUP

Attained Age Group	Observed	Expected	SMR	P-Value
< 45	3	2.01	149	0.3
45 - 54	11	9.34	118	0.3
55 - 64	29	17.52	166	0.007
65+	29	19.00	153	0.02
Total	72	47.87	150	7×10^{-4}

Note: P-values for one sided test of no increase in risk

Table 4

LUNG CANCER RISK IN
MIXED ORE MINERS WHO EVER MINED GOLD

Period of Starting Gold Mining	Observed	Expected	SMR	P-value
Before 1945	55	29.64	186	2×10^{-5}
After 1944	17	18.22	93	
Total	72	47.87	150	7×10^{-4}

P-values one sided test of no increase in risk

Table 5

LUNG CANCER RISK
MIXED ORE MINERS WHO EVER MINED GOLD
BY YEARS WORKED IN GOLD MINES BEFORE 1945 AND ATTAINED AGE GROUP

Years worked in Gold Mines Before 1945	Under 65			Over 65		
	Observed	Expected	SMR	Observed	Expected	SMR
0	15	15.48	97	2	2.75	73
0.1 - 5.0	16	6.42	249	7	4.94	142
5.1 - 10	7	4.89	143	10	5.45	183
10.1 - 15	4	1.61	248	7	3.68	190
15.1 +	1	0.47	213	3	2.18	138
Total	43	28.87	149	29	19.00	153

Table 6

MIXED ORE MINERS WHO EVER MINED GOLD
LUNG CANCER RISK BY X-RAY RATING

X-Ray Rating Subcohort	Observed	Expected	SMR	P-Value
A	49	37.86	129	0.05
B and C	23	10.01	230	3×10^{-4}
Total	72	47.87	150	7×10^{-4}

Note: P-values are for one sided tests.
Subcohorts A, B and C are defined in the Gold Miners Mortality Study page 14.

Table 7

STOMACH CANCER RISKS
IN GOLD AND MIXED ORE MINERS WHO EVER MINED GOLD

	Started Gold Mining in 1945 or Later				Started Gold Mining Before 1945			
Ore	Observed	Expected	SMR	P-Value	Observed	Expected	SMR	P-Value
Gold	19	5.90	322	1.4×10^{-5}	35	28.54	123	0.13
Mixed	4	4.53	88	0.53	8	9.49	84	0.39
Gold and Mixed	23	10.43	220	5.2×0^{-4}	43	38.03	113	0.23

In gold miners there appears to be a significant difference in the risk of stomach cancer according to the time of starting gold mining. Those who started after 1945 appear to be at greater risk than those who started earlier, $p = 1.1 \times 10^{-3}$.

P-values are for one-sided tests.

Table 8

STOMACH CANCERS IN GOLD MINERS
BY ATTAINED AGE GROUPS

Age Groups	Observed	Expected	SMR	P-Value
<50	9	2.29	393	6×10^{-4}
50 - 64	25	14.85	168	0.01
65+	20	17.32	115	0.3
Total	54	34.46	157	1×10^{-3}

Note: P-values are for one sided tests.

There appears to be a significant decrease in risk with increasing age ($p = 0.007$).

TABLE 9

STOMACH CANCERS
IN GOLD MINERS
1955 - 1977

Calendar Period	Year of Starting Gold Mining	Age Group	Observed	Expected	PYAR	SMR	Excess Rate $X10^4$
Before 1969	Before 1945	<50	2	0.63	8033	317	1.7
		50 - 64	8	6.14	14913.5	130	1.2
		65+	5	2.30	1892.5	217	14.3
		Total	15	9.07	24839	165	2.4
	After 1944	<50	2	0.55	14333.5	364	1.0
		50 - 64	1	0.41	1335.5	244	4.4
		65+	0	0.07	60.5	0	-
		Total	3	1.03	15729.5	291	1.3
After 1968	Before 1945	<50	0	0.11	1491	0	-
		50 - 64	9	5.37	15819	168	2.3
		65+	11	13.99	14213.5	79	-
		Total	20	19.47	31523.5	103	0.2
	After 1944	<50	5	0.99	25304.5	505	1.6
		50 - 64	7	2.92	1272.5	240	32.1
		65+	4	0.95	1141.5	421	26.7
		Total	16	4.86	39171	329	2.8
Year of start:							
	Before 1945		35	28.54	56362.5	123	1.1
	After 1944		19	5.89	54900.5	323	2.4
Calendar period of observation:							
	Before 1969		18	10.10	40568.5	178	1.9
	After 1968		36	24.33	70694.5	148	1.7

Table 10

LOG-LINEAR REGRESSION ANALYSIS
OF STOMACH CANCER RISK IN
ONTARIO GOLD MINERS 1955 - 1977

Model	Deviance	DF	Fitted Equation
Constant	34.16	35	ln (RR) = 0.4847
Constant + Age	27.82	34	ln (RR) = 1.588 - 0.185A
Constant + Age + Calendar Period	27.70	33	ln (RR) = 1.565 - .1933A .1074P
Constant + Age + Year of Start	23.17	33	ln (RR) = 0.8995 - 0.1009A + 0.7296Y
Constant + Age + Year of Start + Age x Year of Start	23.10	32	ln (RR) = 1.017 - 0.1195A + 0.5009S + 0.0439AxS
Constant + Age + Calendar Period + Year of Start	23.10	32	ln(RR) = 0.8834 - 0.08382A - 0.1489P + 0.7892S

Notes: A = Age code: 1 means below 40,
2 means 40 - 44, etc.

S = Year of Starting Gold Mining: Code 0 means started before 1945
1 means started after 1944

P = Calendar Period: Code 0 means before 1969
1 means after 1968

RR = Observed number of Deaths/Expected number of Deaths

Note: The effect of age is statistically significant (x^2 = 34.16 - 27.82 = 6.34, df = 1, p = 0.01). After adjusting for age, the effect of period is not statistically significant, (x^2 = 27.82 - 27.70 = 1.82 df = 1) and the effect of starting gold mining after 1945 is statistically significant (x^2 = 27.82 - 23.17 = 4.65, df = 1, p = 0.03). The effect of starting gold mining after 1945 is not modified by Age (x^2 = 23.17 - 23.10 = 0.07) and is not changed if calendar period is also included as an adjustment factor (x^2 = 27.70 - 22.96 = 4.74, df = 1, p = 0.03).

Table 11

GOLD MINERS:
Lung Cancer Risk By Decade
Of Starting Gold Mining

Year First Gold Mining	Under 65				Over 65			
	Observed	Expected	SMR	P-Value	Observed	Expected	SMR	P-Value
Before 1936	42	21.6	195	6×10^{-5}	56	40.4	139	0.01
1936-1944	25	18.0	139	0.07	14	13.5	103	0.5
1945-1954	21	16.5	127	0.2	1	3.56	28	0.1
1955-1964	5	3.3	150	0.2	1	0.53	189	0.4
1965+	0	0.2	0		0	0	-	
Total	93	59.63	156	4×10^{-5}	72	57.99	124	0.04

Note: P-values are for one-sided tests.